Habitat Influence on Fish Community Assemblage in an Agricultural Landscape in Four East Central Indiana Streams

An Honors Thesis (HONRS 499)

By

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April 2003

Expected Date of Graduation

May 2003

ABSTRACT

The objective of this study was to relate the quality of the fish community with the quality of the habitat using the Index of Biotic Integrity (IBI) and Qualitative Habitat Evaluation Index (QHEI) in Buck Creek, Bell Creek, Killbuck Creek, and Little Killbuck Creek in Delaware, Henry and Madison counties IN. The landuse in this area is primarily agriculture, which has caused the creek to be manipulated through anthropogenic practices. Evidence suggests that channelization and substrate are the most influential habitat metrics on fish community assemblage quality. Therefore, to maintain the highest quality fish community in a stream, land owners and land managers need to take steps to prevent stream manipulation through agricultural practices.

ACKNOWLEDGEMENTS

Dr. Thomas Lauer for serving as the advisor and mentor for this project.

The Honors College at Ball State University for their generous funding of this project through the Honors Fellowship Program.

Dr. Thomas Simon for his generous contributions and collaboration of data.

Dr. Mark Pyron for his assistance in the field and for verification of species identification.

INTRODUCTION

Agricultural practices in watersheds have negatively impacted the associated stream habitats, and cause increases in sedimentation and stream channel erosion (Berkman and Rabeni 1987; Gammon 1995; Gammon 1997; Kohler and Hubert 1999; Walser and Bart 1999). Further stream degradation occurs from channelization, which also causes increases in sediment loads, erosion, and gradients, while decreasing riffle and pool abundance, riparian zones, canopy cover, and stream sinuosity (Emerson 1971; Etnier 1972; Chapman and Knudsen 1980; Berkman and Rabeni 1987; Gammon 1995; Gammon 1997; Shields et al. 1998; Wichert and Rapport 1998; Walser and Bart 1999; Gammon at al. 2003). Moreover, livestock allowed in the stream and riparian areas further degrade habitat quality, as animals stir up sediment, erode stream banks, and increase ammonia and nitrite concentrations (Gammon 1995; Gammon 1997; Gammon et al. 2003). Because fish communities are linked to habitat types, when the stream environment is degraded, the fish community suffers as well (Etnier 1972; Gorman and Karr 1978; Scarnecchia 1988; Walser and Bart 1999; Yoder and Smith 1999; Schiemer 2000). Furthermore, the extent of agricultural impacts to the stream environment will further determine the quality of the fish community (Yoder and Smith 1999).

East Central Indiana has an agricultural landscape that covers approximately 70% of the land area (Indiana Agricultural Statistics Service 2001). In addition, many of the streams in this region have been channelized, and are currently in various stages of recovery (pers. obs.). These land uses and alterations are typical for many watersheds throughout Indiana (Indiana Agricultural Statistics Service 2001). Typifying this classification are four tributaries of the White River watershed in Delaware, Henry and Madison IN counties: Killbuck, Little Killbuck, Bell and Buck creeks. All minimally have 70% of their land in agricultural, primarily in a rural setting. In addition, all have historically been channelized, although no channel alterations have occurred to any of these streams since 1987 (pers. corr. Marc Basch, Indiana Department of Natural Resources 2003).

Our objective for this study was to evaluate the relationship between habitat and fish community quality focusing on the effects of agriculture and channelization in these four streams. Habitat was defined using the Quality Habitat Evaluation Index (QHEI) (Rankin 1989), while fish community quality was defined using the Index of Biotic Integrity (IBI) following Simon and Dufour (1998). In addition, we also attempted to defined which components of the QHEI were most influential in structuring the fish community.

METHODS AND MATERIALS

Forty-two sites were located in East Central Indiana (Delaware, Henry, and Madison counties) were chosen for study on four small, agriculturally influenced streams: Bell, Buck, Killbuck, and Little Killbuck creeks (Figure 1). Drainage areas for each stream were: Bell Creek, 71.92 km^2; Buck Creek, 160 km^2; Killbuck Creek, 167.34 km^2; and Little Killbuck Creek, 37.65 km^2 (Hoggatt 1975). Over 70% of the land use in these drainage basins is agriculture (Indiana Agricultural Statistics Service 2001) and all have been historically channelized, but not since 1987 (pers. corr. Marc Basch, Indiana

Department of Natural Resources 2003). Although all streams are in a state of recovery, the majority of the streams still had a straightened channel with little meandering evident. In addition to the altered morphology of the streams, this region has been noted to have soils that are poorly drained and are marked by extensive tile drainage systems (Johnson 2000).

Sampling was conducted in September and October 2001 on Bell Creek, in August 2002 on Buck Creek, and August and September 2002 on Killbuck and Little Killbuck creeks. Fish were collected using a backpack electrofishing unit following the Index of Biotic Integrity (IBI) protocol of Simon and Dufour (1998) designed for the East Central Cornbelt Plain. The distance sampled for each site was 15 wetted widths as visually estimated. All fish collected were identified, weighed, measured, and inspected for anomalies. They were subsequently released back to the stream after processing with the exception of fish difficult to identify or individuals that were used for voucher specimens. Fish not released were preserved in 10% formalin and taken to the lab to complete processing and storage. Individual IBI scores for each site were calculated from the associated fish collections from each site. Drainage basin area was taken from the Hoggatt (1975).

Habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) (Rankin1989), and was conducted at the time of the fish collection. This procedure measured six metrics: substrate, in-stream cover, channel morphology, riparian zone and bank erosion, pool/glide and riffle/run quality, and gradient. Scores were tallied for each metric, and summed providing a total score at each site. Gradient measurements were calculated from the United States Geological Survey topographic maps having a scale of 1:24,000.

To determine whether habitat quality was associated with the quality of the fish community, a comparison was made between IBI and QHEI values at each station using a Pearson Correlation analysis. In addition, the total IBI score was also correlated with individual QHEI metrics (6) to determine association among specific habitat parameters and fish community quality.

RESULTS

Forty-eight fish species were collected from 42 sites in the four streams (Table 1), with the number of species collected at each site ranging from 2 to 21. Sensitive species (Simon and Dufour 1998) were found in all four streams, and included: greenside darter, rainbow darter, least darter, rock bass, smallmouth bass, rosyface shiner, sand shiner, brook silverside, golden redhorse, logperch, least brook lamprey, and northern hogsucker. Five tolerant species were found at over half of the sites and included: blacknose dace, bluntnose minnow, creek chub, green sunfish, and white sucker. Although not falling into either category according to Simon and Dufour's classification, several species were found in high abundance, or at over half the stations, including: mottled sculpin, bluegill, central stoneroller, johnny darter, and orangethroat darter.

Index of Biotic Integrity (IBI) scores (Figure 1) ranged from 14 to 48. The lowest scoring site was located at the upper most headwaters in Buck Creek. At the time of sampling, fish were found in small pools, with flow between pools barely perceptible. Similarly, the second lowest scoring site was on Bell Creek and also was the uppermost headwaters site with little or no flow at the time of sampling. The sites with the highest scores were characterized by having a low percentage of tolerant species coupled with high diversity. Ranges of IBI scores for the four streams were Bell Creek, 26 to 46; Buck Creek, 14 to 38; Killbuck Creek, 30 to 46, and Little Killbuck Creek, 32 to 44.

Qualitative Habitat Evaluation Index (QHEI) calculations ranged from 29 to 83, with the range for each stream as follows: Bell Creek, 48 to 77; Buck Creek, 29 to 64; Killbuck Creek, 31.5 to 78, and Little Killbuck Creek, 39 to 64. (Figure 1). In general, low scores were resultant from the extensive channelization that influenced substrate and channel morphology metrics at all four streams. Some degree of channelization (recovered or recovering as categorized in the QHEI channel morphology metric) was found at 36 of the 42 sites. Most of these sites also had low sinuosity, further lowing habitat quality scores. The lowest QHEI score was found at the most upstream site of Buck Creek, where there were no pool or riffle developments due to the lack of flow. In addition, cattle had access to the stream, eroding banks, altering substrate, and destabilizing riffle/run development. Several other sites on Buck and Bell creeks allowed cattle access, and these same habitat alterations were observed. Most sites also showed little riparian area development, with row crops often at or near the waters edge, even at low, late summer flow regimes. In contrast, the highest score was located on Bell Creek, which had excellent pool/glide and riffle/run development, as well as good channel morphology development.

A positive correlation was shown between QHEI and IBI scores at each station ($n=42$, $p<0.001$, $r^2=0.524$), indicating the fish community quality improved with increasing habitat quality (Figure 1). The specific habitat components influencing the fish community were identified after correlating individual QHEI metrics (6) with the total IBI score for each station (Table 1). From this analysis, changes in channel morphology were found to be the most influential habitat component structuring the fish community assemblage. Also significantly influencing the fish community were the substrate and pool/glide and riffle/run quality components of the QHEI, while in-stream cover was also found to have some influence on IBI scores. Finally, this analysis showed that riparian zone and bank erosion, and stream gradient metrics had no influence on the IBI scores for the creeks sampled. This was expected as all sites sampled had similar habitat structure for these metrics.

DISCUSSION

Agriculture comprises 70% of the land use of the four stream basins we sampled in East Central Indiana, closely mimicking the landscape in the rest of Indiana and the Midwest (Indiana Agricultural Statistics Service 2001). This type of use severely changes the natural landscape, including the removal of riparian zone vegetation, the addition or removal of nutrients to the soil, denuding the vegetation during portions of the year, and the channelization of streams (Hupp 1992; Wichert and Rippart 1998; Walser and Bart 1999). These changes in the terrestrial use focus on increasing efficiency and profit for the agricultural industry. However, they also negatively impact the aquatic communities associated. Our findings for four East Central Indiana streams suggests that as the terrestrial habitat is increasingly altered from agricultural practices, the fish community quality is correspondingly lowered. These findings are similar to other studies in this type of landscape (Walser and Bart 1999; Schiemer 2000).

Channel morphology was the most influential habitat parameter driving fish community quality in these four streams, and is likely resultant from the extensive channelization that has occurred in the past. Thirty out of the forty-two sites were in a state of recovery from channelization, with most still visibly showing a morphological straight channel. When a channel is straightened and shortened, all riffle and pool habitats are removed (Carline and Klosiewski 1985), lowering habitat diversity (Etnier 1972; Gorman and Karr 1978; Chapman and Knudsen 1980; Carline and Klosiewski 1985; Portt et. al 1986; Scarnecchia 1988; Hupp 1992; Zalewski and Welcomme 2001; Muotka et. al 2002). A channelized stream is a fast flowing run, or typically, a stream with a high, non-turbulent velocity having a depth deeper than a riffle (Rankin 1989). Because channelization causes a higher velocity, a higher gradient, and an increase in erosion, the substrate is extremely unstable and lacking variability (Emerson 1971; Etnier 1972). All sites along Buck Creek were composed of over 80% run, a feature that was also commonly found in the other three streams. Moreover, only nine of the total sample sites (n=42) had a high substrate diversity (QHEI metric: substrate), further suggesting channelization reduces stream habitat diversity.

This reduction in stream habitat due to channelization reduces fish community quality (Etnier 1972; Gorman and Karr 1978; Scarnecchia 1988), a finding we observed in our study area. For example, a lower scoring IBI site on Buck Creek that was recovering from being channelized had no riffles, low sinuosity, and was composed of 5% pool area. This site had only one species of darter, likely due to the lack of riffle habitat and only two species of sunfish due to the lack of pool habitat. In contrast, the highest IBI score was found on Killbuck Creek, where no channelization was evident and pools, runs, and riffles existed in similar amounts. Four species of darters and five species of sunfish were found at this site, substantiating the relationship between land use and fish community quality.

Stream degradation will also change the composition of the fish living there based on tolerance levels (Rankin 1989; Smoger and Angermeier 1999). A channelized stream becomes dominated by tolerant species and lacks sensitive species in high abundance. Tolerant species have the ability to be thrive in environments altered by anthropogenic practices, while sensitive species have a decreased range of environmental tolerance and are typically not found in degraded habitats (Smoger and Angermeier 1999). We found the highest QHEI scoring site on Killbuck Creek had the lowest percent of tolerant individuals and the highest number of sensitive species. In contrast, the lowest QHEI score for Killbuck Creek had the largest percent of tolerant individuals.

This study also suggests that degradation in habitat quality existed long after the channelization activity took place. Diversity and stability of the stream communities only occurs after a period of recovery that allows succession to transpire (Hupp 1992; Muotka et. al 2002). For example, as the stream channel is restored and anthropogenic practices are minimized, diverse habitats, such as variable substrates, water velocities, and instream cover, are reestablished. Sites with well developed habitats can be expected to have a diverse fish assemblage, while poorly developed sites will have a correspondingly tolerant fish community (Scarnecchia 1988). Using this model, tolerant species would be the first to colonize, while sensitive species would be reestablished only after riffles and pools were restored. In our study, the highest scoring site on Killbuck Creek where no channelization had ever occurred had 13% tolerant species while the lowest IBI scoring site had 59% tolerant species. This indicated the most pristine conditions for this region were able to support more diversity in the fish assemblage than just tolerant species while the lower scoring site would need to re-establish a natural channel in order to support more than just tolerant species.

Another metric in our study that influenced the fish community assemblage was substrate quality. As more land is turned into agriculture, more of the soil runs off in to nearby streams, reducing substrate diversity and quality (Walser and Bart 1999). Sedimentation in the Upper White River Watershed is a major concern, and a report conducted by the USEPA from 1980- 1993 indicated that a reduced sediment load is needed through reduction of erosion on the farm fields (Bothel 2000). Personal observations indicate that these heavy sediment loads still occur within this region. As this sedimentation enters the water, visibility, light penetration, and sedimentation diversity decrease. This runoff creates a less diverse substrate, which in turn, decreases the diversity of the fish present because fewer microhabitats are present to support different fish species (Frothingham et al. 2002). As the distinction among riffle, run and pool substrates decreases due to siltation, the fish community similarly decreases (Berkman and Rabeni 1987). This sedimentation further aggravates the loss of diversity due to channelization in these streams.

According to our results, changes made to riparian zones had no effect on fish community assemblages for the streams sampled. The riparian zone metric did not significantly affect the IBI scores of these streams because the riparian zones at each site were nearly identical. Thus, with no difference in this metric between the sites, no significance was detected. However, we feel that riparian zones are an important metric in maintaining fish community integrity. Walser and Bart (1999) found that fish diversity was significantly lower in streams where agriculture was draining into than streams surrounded by forest. Riparian zones help prevent fertilizers and pesticides, as well as sedimentation runoff into streams. According to Wichert and Rapport (1998) if riparian zone vegetation was unaffected or reestablished, fish community assemblages would respond positively.

Anthropogenic practices have caused the stability of the fish assemblage to be lost. Even if a stream is left to recover to be restored to its natural condition, the diversity of the fish assemblage may slowly be reinstated, but the assemblage will not be stable. Stability of a fish assemblage cannot be achieved until all anthropogenic practices that negatively alter the lotic environment are discontinued in that watershed (Gorman and Karr 1978). This points to the need for more land management enforcement especially targeting the most significant factor, stream channelization. Supporting this view, the Indiana Department of Natural Resources comment, "All of the other existing efforts by state agencies in permitting, Lake and River Enhancement, fisheries management, wetland legislation, and other actions to protect stream water quality and aquatic communities may be completely negated for some streams if we cannot control stream channelization projects conducted under the current drainage code" (personal correspondence Gwen White 2003) Unfortunately, the four East Central Indiana streams have already been channelized, and poor agricultural practices still happen. These streams may be in a state of recovery, but may never reach its full potential with a stable habitat and stable fish assemblage.

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Table 1. Number of sites out of the 42 sites where each species was collected and the tolerance category of each species.

Species	Scientific Name	No. Stations	Classification
Black Bullhead	*Ameiurus melas*	1	Tolerant
Black Crappie	*Pomoxis nigromaculatus*	1	-
Blacknose Dace	*Rhinichthys atratulus*	24	Tolerant
Blackside Darter	*Percina maculata*	4	-
Blackstripe Topminnow	*Fundulus notatus*	7	-
Bluegill	*Lepomis macrochirus*	23	-
Bluntnose Minnow	*Pimephales notatus*	21	Tolerant
Brook Silverside	*Labidesthes sicculus*	1	Sensitive
Central Stoneroller	*Campostoma anomalum*	25	-
Common Carp	*Cyprinus carpio*	11	Tolerant
Creek Chub	*Semotilus atromaculatus*	38	Tolerant
Fathead Minnow	*Pimephales promelas*	3	Tolerant
Golden Redhorse	*Moxostoma erythrurum*	3	Sensitive
Golden Shiner	*Notemigonus crysoleucas*	3	Tolerant
Grass Pickerel	*Esox americanus*	10	-
Green Sunfish	*Lepomis cyanellus*	37	Tolerant
Greenside Darter	*Etheostoma blennioides*	22	Sensitive
Horneyhead Chub	*Nocomis biguttatus*	2	Sensitive
Johnny Darter	*Etheostoma nigrum*	34	-
Largemouth Bass	*Micropterus salmoides*	5	
Least Brook Lamprey	*Lampetra aepyptera*	7	Sensitive
Least Darter	*Etheostoma microperca*	1	Sensitive
Logperch	*Percina caprodes*	7	Sensitive
Longear Sunfish	*Lepomis megalotis*	8	Sensitive
Mottled Sculpin	*Cottus bairdii*	36	-
Northern Hogsucker	*Hypentelium nigricans*	16	Sensitive
Orangethroat Darter	*Etheostoma spectabile*	28	-
Pirate Perch	*Aphredoderus sayanus*	4	-
Rainbow Darter	*Etheostoma caeruleum*	10	Sensitive
Redear Sunfish	*Lepomis microlophus*	4	-
Redfin Shiner	*Lythrurus umbratilis*	2	-
Ribbon Shiner	*Lythrurus fumeus*	1	-
River Shiner	*Notropis blennius*	1	-
Rockbass	*Ambloplites rupestris*	12	Sensitive
Rosyface Shiner	*Notropis rubellus*	3	Sensitive
Sand Shiner	*Notopis stramineus*	3	Sensitive
Silverjaw Minnow	*Ericymba buccata*	2	-
Smallmouth Bass	*Micropterus dolomieu*	7	Sensitive
Spotfin Shiner	*Cyprinella spiloptera*	3	-
Spotted Bass	*Micropterus punctulatus*	4	-
Spotted Sucker	*Minytrema melanops*	3	-
Striped Shiner	*Luxilus chrysocephalus*	9	-
Suckermouth Minnow	*Phenacobius mirabilis*	1	-
Tadpole Madtom	*Noturus gyrinus*	1	-
Threadfin Shad	*Dorosoma petenense*	1	-
Western Mosquito Fish	*Gambusia affinis*	1	-
White Sucker	*Catostomus commersonnii*	32	Tolerant
Yellow Bullhead	*Ameiurus natalis*	4	Tolerant

Table 2. Correlation between total IBI and QHEI (total and individual metrics) scores for 42 sites located in four East Central Indiana streams.

	p	r^2
QHEI (Total score) vs. IBI	<0.001	0.524
QHEI (Individual metrics) vs. IBI		
Channel Morphology	<0.001	0.534
Substrate	0.004	0.432
Pool/Glide and Riffle/Run Quality	0.008	0.404
Instream Cover	0.014	0.377
Riparian Zone and Bank Erosion	0.077	0.276
Stream Gradient	0.439	-0.123

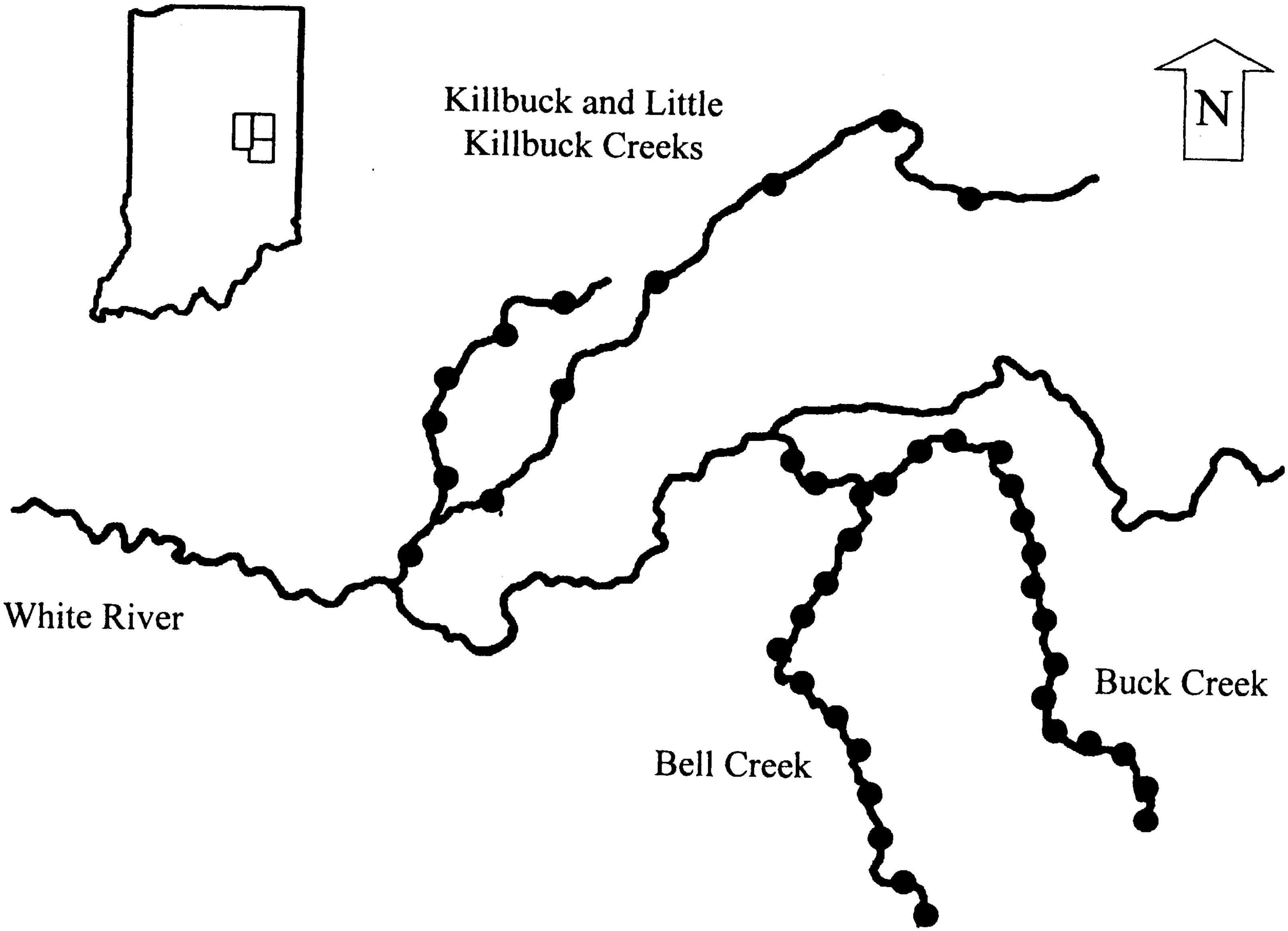

Figure 1. Study area of the four streams in East Central Indiana.

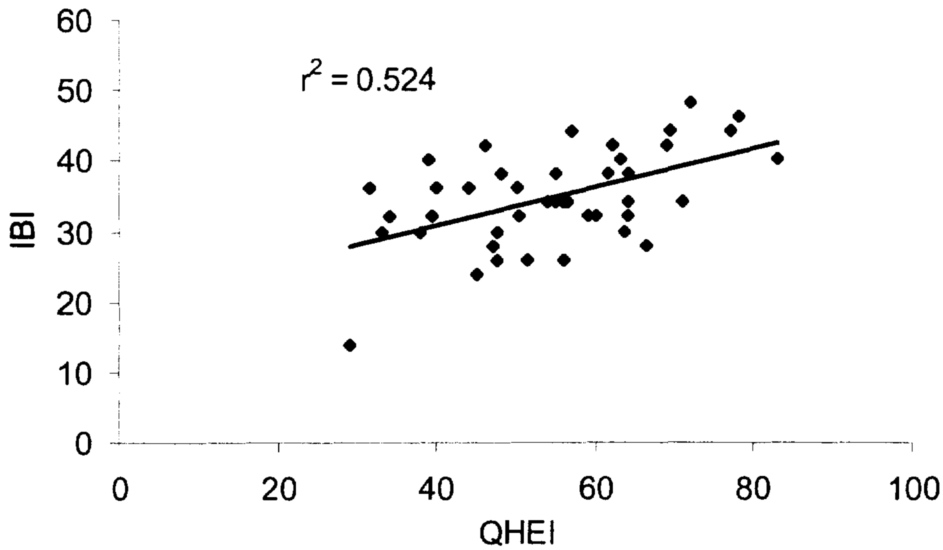

Figure 2. IBI score and QHEI score relationships of the 42 East Central Indiana streams ($p < .001$).